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# AD819940

# STABILITY OF FREQUENCY-WAVENUMBER NOISE SPECTRA AT UBO

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By

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Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY Nuclear Test Detection Office ARPA Order No. 624 BEST AVAILABLE COPY

# STABILITY OF FREQUENCY-WAVENUMBER NOISE SPECTRA AT UBO

# SEISMIC DATA LABORATORY REPORT NO. 197

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# AVAILABILITY

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#### ABSTRACT

Seven four-minute samples of the ambient noise were subjected to frequency-wavenumber (F-K) spectral analysis in order to observe the range and character of variations in the F-K power spectrum. The observations are derived from the same normal population. The apparent variation in the underlying noise statistics or processes do not suggest gradual diurnal variations in the noise power, but large and apparently random inter-day fluctuations.

#### PROCEDURE

The SDL wavenumber-frequency analysis program VFKSPTRM due to McCowan and Jih was used to analyze seven four-minute samples of ambient noise recorded at the UBO vertical array on 14 April 1967, starting at 3/20/00.00, 4/42/00.0, 6/20/00.0, 9/00/00.0, 11/20/00.0, 14/00/00.0, and 15/15/00.0. Spectral peaks were observed at nearly infinite vertical velocity at 0.20 cps, 0.80 cps, 1.50 cps, and 2.00 cps. The variability of power observed at these frequency was subjected to Bartlett's test for homogeneity of variance (Kullback, 1959). For better accuracy the high frequency peaks were observed after bandpass filtering in order to prevent leakage through the spectral window due to the large .20 cps peak.

## TIME VARIATION OF THE SPECTRAL PEAK

Table 1 lists relative values of the spectral power observed at different times during the day at the specified frequency of F-K peaks observed in the noise. The vertical wave number of the peaks is nearly zero in all cases.

The .2 cps noise power was taken from the F-K spectral plots on Figures 1 to 7 with all observations normalized to the mean at .2 cps. The strip at the bottom of the Figures show the array response. The other observations were taken from the power spectral plots of band passed (.3 to 3 cps) data on Figures 8 to 14.

# MEAN, RANGE, AND STABILITY OF PEAK POWER AT EACH FREQUENCY

The arithmetic mean value observed for the spectral peaks in the noise is taken from Table 1, as is the range between the lowest and highest observation in the time interval between 3/20/00.0 and 15/19/00.0. The parameter t is measured for testing the hypothesis that the observed variability of variances is due to sampling and that the underlying

variance of the noise field is time invariant

T = 2(BT) (B'X) 
$$\sum_{i=1}^{7} \log S^2/S_i^2 S^2 = \frac{1}{7} \sum_{i=1}^{7} S_i^2$$

where B is bandwidth of frequency analysis

T is time-length of sample

X is length of the vertical array

B' is bandwidth of wave number analysis.

There is no spatial smoothing in the program, so  $B'X \approx 1$ . This can be verified from the array response (using 3 km. for the length of the array). The smoothing of power in time results in  $B \approx .05$  cps and the time-length of the sample is 204 sec. The results of the t test are shown on Table 2. For acceptance of the hypothesis of homogeneity of variance t should be less than 12.63 in Fisher's  $B^2$  distribution.

#### RESULTS

The probability of error in rejecting the hypothesis that the .2 cps noise is stationary is considerably greater than 0.05, and therefore we should not reject, but the power for acceptance of stationarity is probably low for this test. The result for the 0.8 cps peak is also marginal. We reject stationary recognizing that the probability of error is close to 0.05 if the statistics and processes underlying the .8 cps peak are indeed stationary. In the case of the high-frequency peak at 1.5 cps and 2.0 cps respectively we can decisively reject the hypothesis that the random variates underlying the observed sample variances are from the same noraml population. The high-frequency noise above 1 cps appears to be very non-stationary when viewed over a 12 hour time span. There is no obvious diurnal trend in the observed spectral power of the high-frequency

peaks.

The character of the noise as seen on Figures 1 through 4 shows a high degree of symmetry, indicating that energy conversions resulting in more up-going or down-going energy are not "observed" to play an important role in the ambient noise. There is no obvious indication of reflected P-pulses although such noise may be obscured by the array response.

#### REFERENCES

Kullback, S., Information Theory and Statistics, Wiley, 1959, p. 319.

TABLE 1

Time Frequency	3/20/ 00.0Z	4/42/ 00.0Z	6/20/ 00.0Z	9/00/ 00.02	11/20/ 00.02	14/00/ 00.02	15/15/ 00.0Z	Mean
.2 cps	1.35	1.02	1.14	0.79	1.05	ή9.0	1.02	1.00
.8 cps	0.04	0.10	0.06	0.03	0.05	0.03	0.06	0.06
1,5 cps	900.0	0.010	0.037	0.001	0.007	0.002	0.035	0.014
2.0 cps	0.011	0.003	0.002	0.005	0.010	0.034	0.002	0.017

TABLE 2

Frequency	Mean Power	Range of Power	t	Hypothesis of Homogeneity
.2 cps	1.00	0.64-1.35	9.7	Accepted
.8 cps	0.06	0.03-0.10	12.9	?
1.5 cps	0.014	0.001-0.037	91	Rejected
2.0 cps	0.017	0.002-0.055	98	Rejected

#### VEKSPIRM AMBIENT HOISE, UBO. STARTING AT 3/20/0 Z

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	HONTHING TIME . >			

			u w	OTHOOL
GRANNEL 18	SCALE FACTOR	DOPTH		•
Dus.	1.00	0.710	6 - V	•
043	1.00	0.110	15 - 19	•
044	1.09	1.000	10 - V1	•
• 45	1.00	1.4*0	04 - 07	•
for a	1.00	1:14		

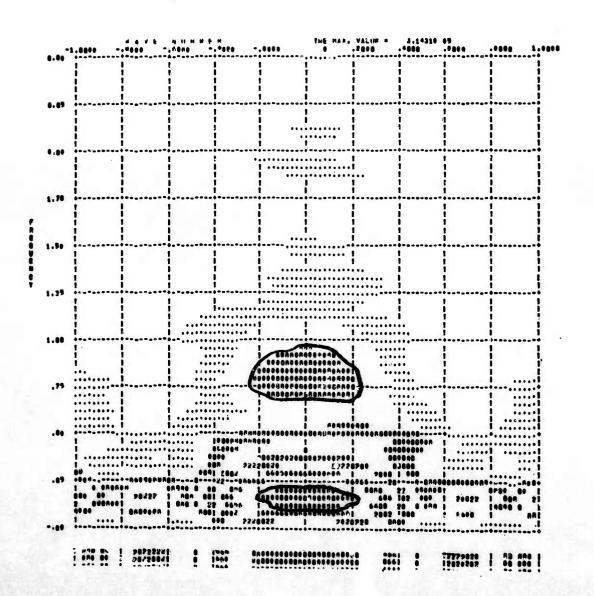


Figure 1. Unfiltered Noise

#### VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 4/42/00.0 Z

\$610MnGMAN MP. m \$1600		NO. OF CHANNEL . 9
SAPPLING PATE . 28.88 STARTING ROINT .	1	TOTAL POINTS . 4008
THE SHRUGH UP SHORTHING IINI . 5		•

CHANGE ID	SCALE FACTOR	PORTH	D •	SAMBOF
Dut	1.00	2.710		•
9+3	1.00	2.110		•
044	2.00	1.000	12 - 1>	•
0+5	1.00	1.400	10 - 21	•
046	1.00	1.130	24 - 27	

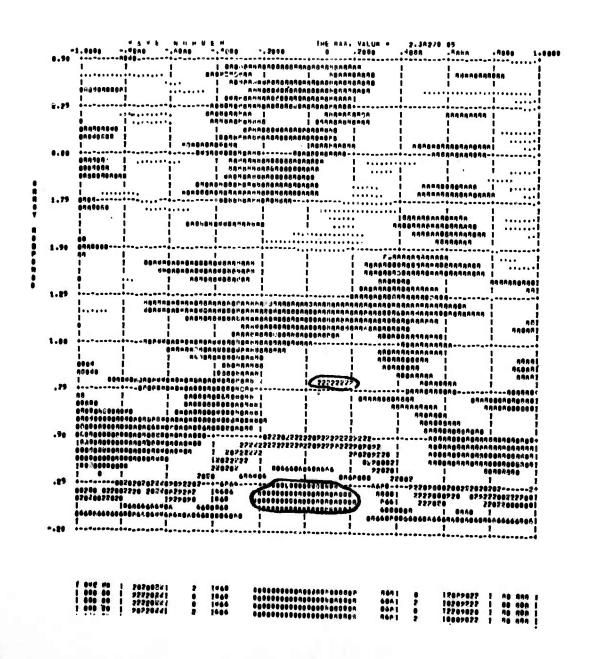


Figure 2. Unfiltered Noise

#### VEKSPTRM AMBIENT NOISE, UBG. STARTING AT 6/20/0.0 Z

0015M00848 NO. H 11641

NO. OF CHANNEL . 9

BARRLING HATE . 20.00

BIARITUG FOINT .

1 701AL PRINTS - 4896

THE MINAGE UP ENGOTHING TIME . >

CHANGE ID	SUALE FACTOR	DERTH		
Dus	1.00	2.710	D A	SYMBOL
gu3	1.00	2.110		•
Du4	1.00			•
		1.000	12 - 19	2
Dus	1.00	1.470	10 - 21	
Due	1.00	1.130		•
			24 - 27	

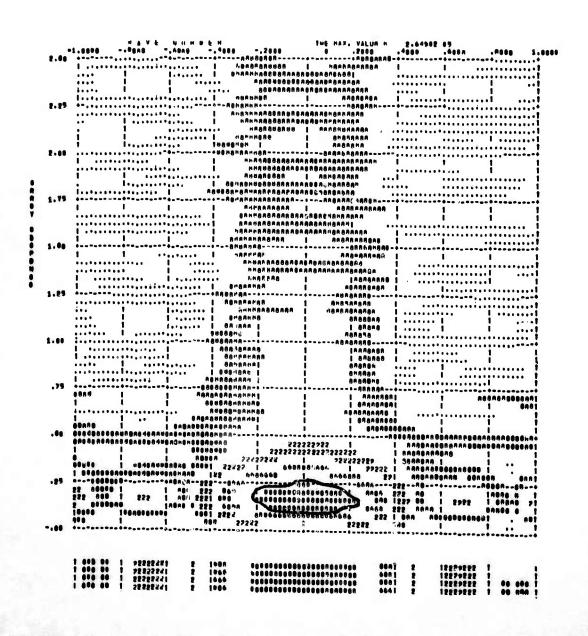


Figure 3. Unfiltered Noise

## VFKSPTRM AMBIENT NOISE. UBO. STARTING AT 3/00/00.0 Z

961 SMOGHAM NO. . 11842

NO. OF CHANNEL . 5

SAMPLING hale m ga. us

Statifie Point .

INTAL POINTS . 4890

THE MINISH UP BODOTHENS TIME . 7

GRANINGE TO	SCALE FACTOR	DEPTH		
Dus	1.00	2.710	<b>U</b> A	BYHOOL
U=3	1.00	2.110		•
Due	1.00	1.000		•
Dug	1.00	1.400	18 - 19	2
Due	1.00	1-136	10 - 71	•
			24 - 27	

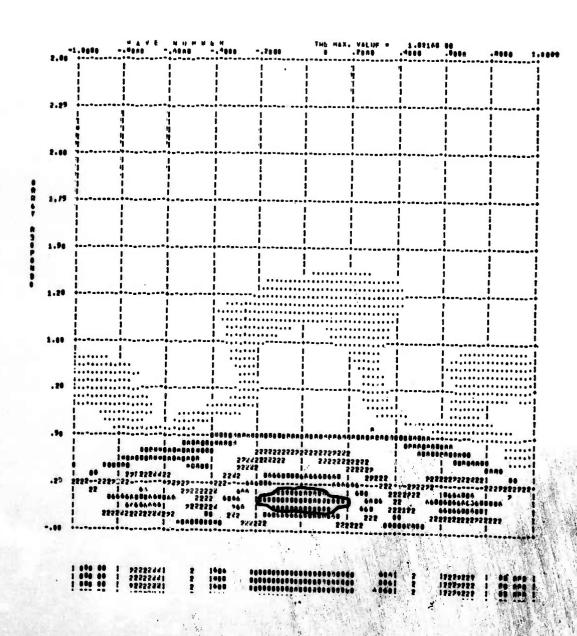


Figure 4. Unfiltered Noise

#### VEKSPTRM AMBIENT NOISE, UBO, STARTING AT 11/20/00.0 Z

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9#   WHOM 44P 40.	•  11003		NO. OF CHARMEL . 9	
-	28.00 BTAHILMS	**************************************	TOTAL POINTS - 4846	
	C . THIT BRINTON			

CHANNEL ED	SUALE FACTOR	DEPTH	<b>U N</b>	6 44801
Dus	1.00	2.710	8 - 3	•
043	1.00	2.110	A - V	•
Du4	1.00	1.600	18 - 15	•
Dug	1.00	1.470	16 - 21	•
0ue	1.00	1.430	44 - 47	

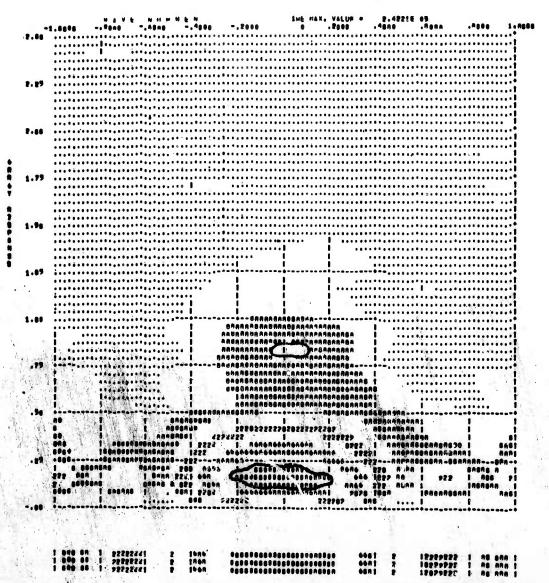


Figure 5. Unfiltered Noise

VEKSPTRM AMBIENT NOISE. UBO, STARTING AT 14/00/00.0 Z

 - 11404			NO. OF CHANNEL	• •
 20.00 81441	ING POINT .	1	TOTAL POINTS	. 4070
 ** ************	•			

CHANNEL ID	SCALE FACTOR	DESTH		
		2.710	<b>U</b> •	STHOOL
Bu1	1.00		1 - 1	2
D+2	1.00	8.110		•
DH4	1.00	1.000	• •	•
Dus	1.00	1.490	12 - 15	
			10 - 21	•
0+0	1.00	1.130	24 - 42	

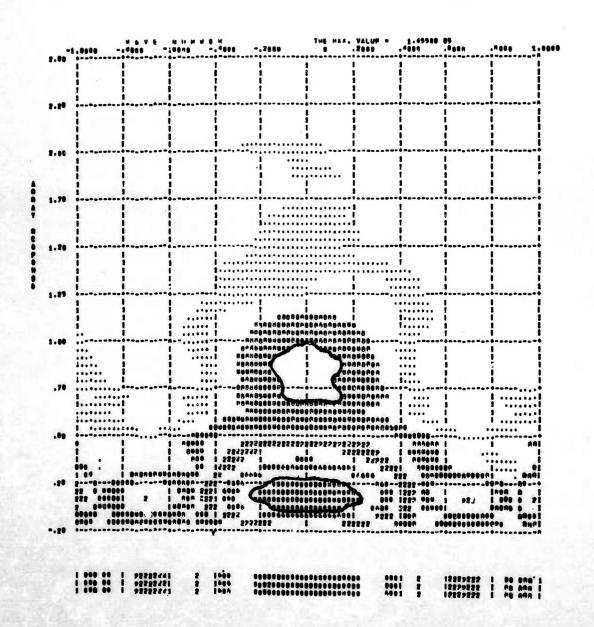


Figure 6. Unfiltered Noise

#### VEKSPTRM AMBIENT HOISE, UBO, STARTING AT 15/15/00.0 Z

BOI SHOCKAP HO.	- 11000	NO. OF CHANNEL . 5
SUMPLING HATE N	28-88 STANTING POINT . 1	TOTAL PRINTS A 4896
-	menting time . 5	

CHONNEL IS	SCALE FACTOR	DOPTH		
941	1.00	7.710	• •	SYNOOL
943	1.00	2-110		•
944	1.00	1.000	6 - 1	•
848	1.00	1.490	18 - 19	,
Due	1.00	1.130	10 - 01	
			24 - 21	

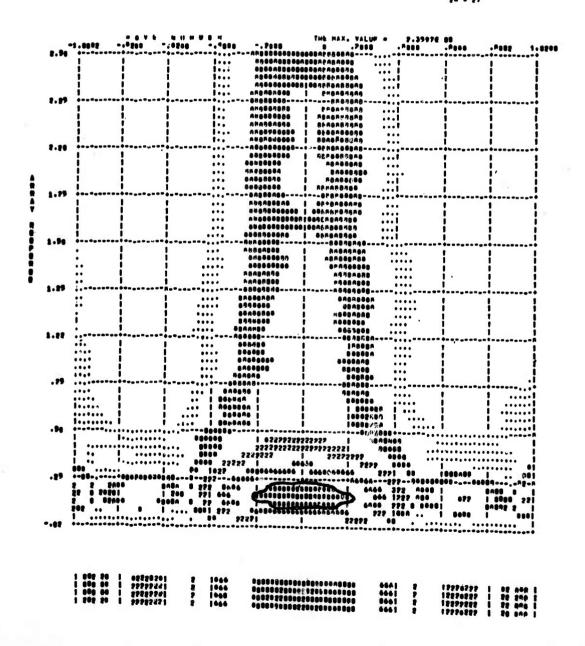


Figure 7. Unfiltered Noise

### VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 3/20/00.0 Z

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DHI	1.00	2.710		•
U+3	1.00	2-110	4	•
444	1.00	1.000	12 - 19	2
Dus	1.00	1.000	10 - 21	•
iles.	1.00	1.130	24 - 21	

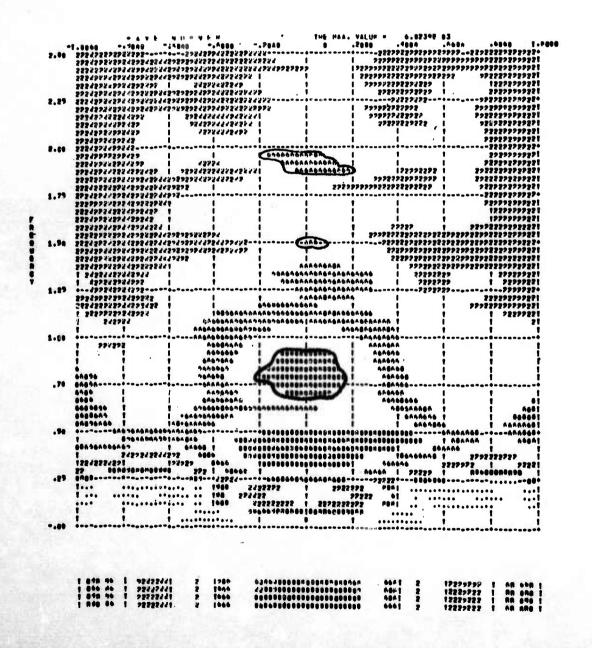
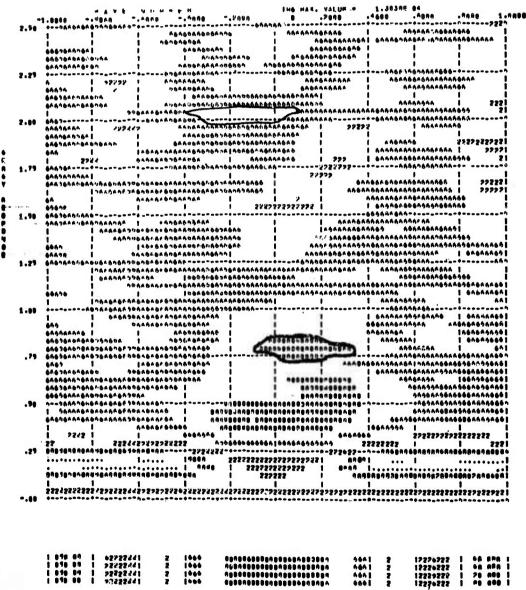


Figure 8. Filtered Noise Band: (.3<f<3cps)
Rolloff: .lcps

# VEKSPIRM AMBIENT NOISE, UBO. STARTING AT 4/42/00.0 Z

NO. OF CHANNEL 5 5 \$6.5 mmunah mm. a \$1698 SIANING PUINT . 1 TOTAL POINTR # 1870 ----

			υ <b>#</b>	BIMBOL
CHANCEL ID	STALE FACTOR	DEPIN		
UH1	1.00	2.710		•
U~ 3	1 < 00	4.110	12 - 15	2
3-14	1.00	1.000	10 - 21	
UHS	1.00	1.400	24 - 11	



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Figure 9. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

#### . VEKSPIRM AMBIENI NOISE. URO, STARTING AT 6/20/00.0 Z

			ti se	8 148 OF
CHANCEL ID	SCALE TALTUM	De # to	0 - 3	
UHT	1.00	2.718	A • ¥	•
Dir 3	1.00	2.110		,
yw <b>a</b>	1.04	1.858	17 - 17	•
Dus	1.08	1.000	10 - 21	•
	1.00	1.130	24 - 21	•
DHA		11100		

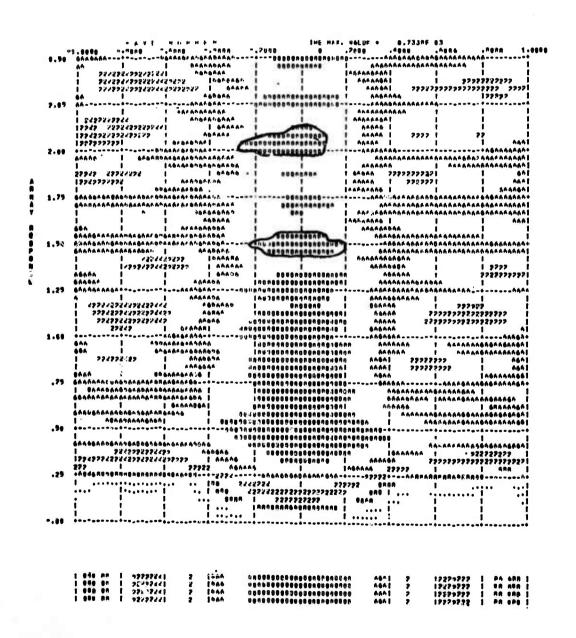


Figure 10. Filtered Noise Band: (.3<f<3cms)
Rolloff: .lcps

#### VEKSPTRM AMBIENT NOISE. UBO. STARTING AT 9/00/UO.0 Z

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			12 - 1>	
4-3	1.08	1.486	10 - 21	
<b>B</b> +46	1.00	1.130	10 - 21	•
			28 - 27	

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Figure 11. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

#### VEKSPTRM -MBIENT NOISE, UBO. STARTING AT 11/20/00.0 Z

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CHANCEL IN	SUALE PACTOR	DEPTH		
Del	1.00	2.710	n e	STATE
Unio	1.00	2.110	0 - 3	•
ULA	1.00	1.000	• • •	•
Urb	1.00	1.400	12 - 1b	
Uma	1.00	1.150	10 - 21	•
	•		29 - 41	

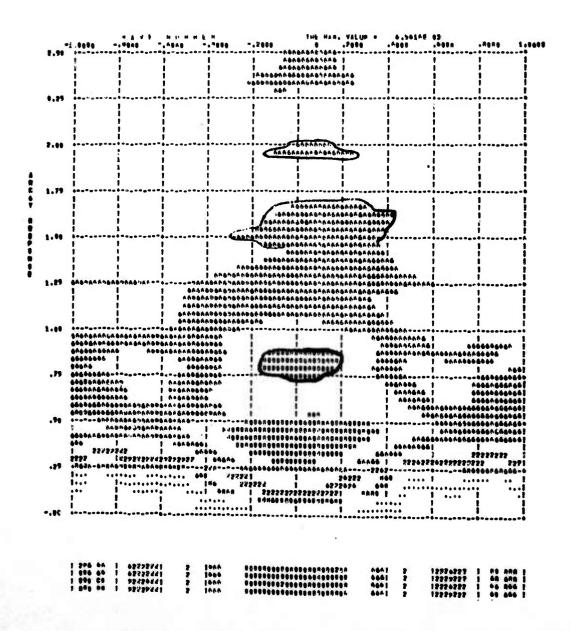
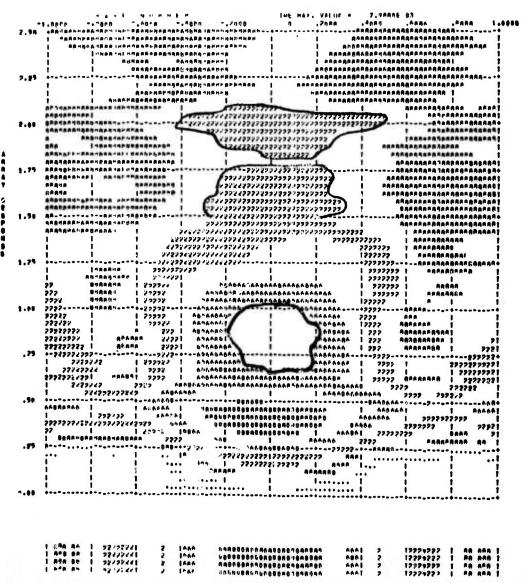


Figure 12. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

# VEKSPTRA AMBIENT NOISE. UBD. STARTING AT 14/00/00.0 Z

NO. OF CHANGET . ABRE . FINIOR JATOS SAMPLING Hold & Joseph MOROSE OF SECURING TIPE . 5

umamiji lip	STATE FACTOR	DERTH	j: 4g	87# <b>90</b> L
po-1	7.00	2.710		
****	141		n - 3	•
Dw.5	1.00	2.110		
			A - Y	•
the 4	1.49	1.000		_
			19 - 19	
045	1.00	1.498		
			10 - 21	•
UNA	1.66	1.138	20 - 41	



1 A*8 BR	1 25175	441 2	1000	1000	2	12229227	į	-	888 888 888	İ

Figure 13. Filtered Noise Band: (.3<f<3cps) Rolloff: .1cps

#### VEKSPTRM AMBIENT HOISE, UBO, STARTING AT 15/15/00.0 Z

SELTANDUMEN NO. 0 11005 NO. 01 CONNEL N 0 GARLING MOTHS + 1 TOTAL ROTHES + 4866

THE NUMBER OF SUGNITIES 1106 0 5

		D021H	BLALE FACTOR	CHANGE ID	
0 THOGL	U 6	2.718	1.00	D=1	
•	9 - 1	2.110	1.00	Dr. 3	
•	6 - Y	1.000	3.00	U=4	
•	12 - 15	1.470	1.00	Dug	
•	10 - di	1.130	1.00	Uwb	
	26 - 21				

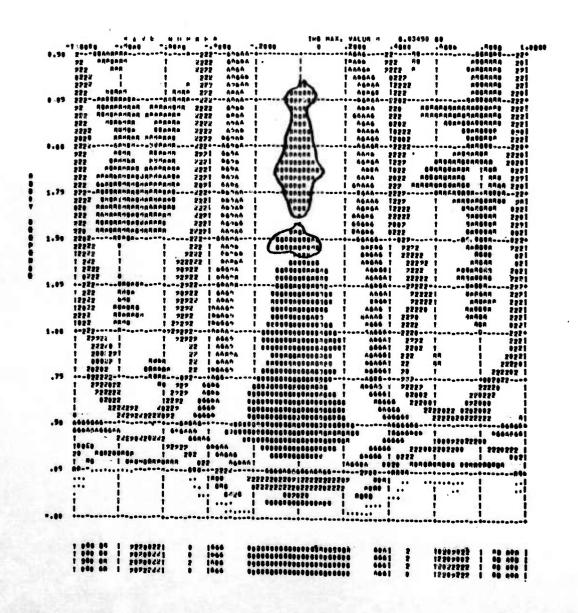


Figure 14. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

DOCUMENT (Security classification of title, body of abstract and inc	CONTROL DATA - R&			
ORIGINATING ACTIVITY (Corporate author) TELEDYNE, INC. ALEXANDRIA, VIRGINIA		Unclassified		
STABILITY OF FREQUENCY-WAVENUE	MBER NOISE SPE	ECTRA AT UBO		
4. DESCRIPTIVE NOTES (Type of report and Includive dates) Scientific				
B. AUTHOR(S) (Leel name, Hitel name, Initial) Sax, Robert L.				
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Seven four-minute samples of the ambient noise were subjected to frequency-wavenumber (F-K) spectral analysis. In order to observe the range and character of variations in the F-K power spectrum. The observations are derived from the same normal population. The apparent variation in the underlying noise statistics or processes do not suggest gradual diurnal variations in the noise power, but large and apparently random interday fluctuations.

Unclassified

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14.	KEY WORDS		LINK	A WT	LINE	B	HOLE	C
Seismology Microseism Seismic Noise Spectrum Stationarity		]} ==0.01	AUCE	***	HOLE	**	NOLL	**
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